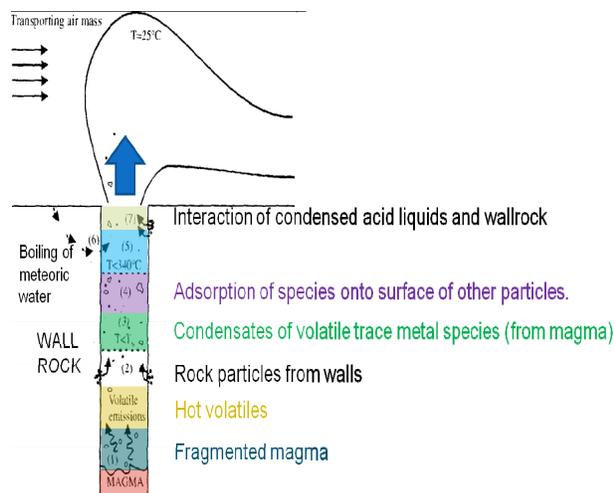


**DEGASSING OF VOLATILE-BEARING MARTIAN MAGMA INTO A CO<sub>2</sub>-RICH ATMOSPHERE** H. Nekvasil<sup>1</sup>, G. Ustunisik<sup>1</sup>, and D. H. Lindsley<sup>1</sup>, <sup>1</sup>Department of Geosciences, Stony Brook University, Stony Brook, NY 11794-2100 [Hanna.Nekvasil@stonybrook.edu](mailto:Hanna.Nekvasil@stonybrook.edu)

**Introduction:** Ascending magmas likely played a major role in the development and evolution of the martian surface and atmosphere because of their dissolved volatile load. This volatile load may have been modified from that of the original magma by fractionation of volatile-bearing phases such as kaersutitic amphibole and loss of magmatic fluids during fluid exsolution within the crust. Yet, even the volatiles remaining in the magma as it reaches the near-surface environment may not be contributed completely to the atmosphere because of (a) differential degassing of volatile species from the magma, (b) condensation or sublimation of volatile species in the vent and adsorption onto rock particles, and (c) loss of condensate by interaction with wallrock and formation of alteration assemblages (Fig. 1).



**Figure 1.** Schematic illustrating vent processes at the magma-surface-atmosphere interface (Modified from [1]).

Degassing is controlled by gas/melt equilibria and some volatiles, such as F, partition into the melt more strongly than others at low pressures (e.g., water) and may be retained by a lava upon extrusion and temperature quench. In this way, the composition of the gas exsolved may differ from the magmatic volatile load. However, even the gases formed may not be contributed in their entirety to the atmosphere. Degassing of halogen- and S-bearing magma likely involves the formation of metal halogen and sulfide or sulfate gaseous species. These may form condensates or sublimates that can become part of the surface soil or react with rock particles, becoming sequestered in alteration

minerals. Both processes would limit their contribution to the atmosphere.

We have initiated a comprehensive experimental study of the igneous processes involving gaseous exsolution at the surface/atmosphere interface, starting with understanding differential degassing and moving into alteration induced by interaction of soil and rock with magmatic vapors.

The compositional nature of the atmosphere into which a magma degasses may influence both the extent of degassing and the nature of the gaseous species produced. Recent suggestions of an early CO<sub>2</sub>-rich martian atmosphere are supported by carbonate-bearing lithologies [e.g., 2-3]. However, later lithologies show no evidence that this was sustained throughout martian history. For this reason, experiments were designed to evaluate degassing in both CO<sub>2</sub>-rich and CO<sub>2</sub>-poor atmospheres.

**Experimental Design:** Preliminary experiments were designed here to simulate degassing of a volatile-rich Martian magma that ascended rapidly and retained much of its volatile load until eruption onto the surface at a pressure of approximately 0.6 bars.

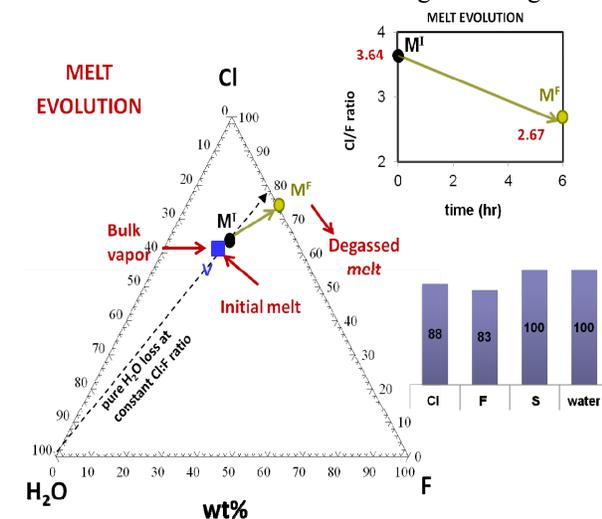
**Experimental Details:** The Martian composition proposed to simulate the melt trapped as melt inclusions in the Chassigny dunitite [4] (B1050) was synthesized with 1.2 wt% Cl, 0.35 wt% F, 0.12 wt% S, and 0.4 wt% water (Table 1). Sealed evacuated silica tubes were used which hosted the synthetic volatile-bearing Martian basalt, a capsule containing the FMQ oxygen buffer assemblage, and a separate capsule containing a CO<sub>2</sub> source. These tubes were suspended with a Pt-wire in a vertical quench furnace and heated above the liquidus temperature to permit degassing. Based on the amount of gas given off from the CO<sub>2</sub> source and from the melt, the pressure was calculated as ~0.6 bars.

	<b>B1050</b>
<b>SiO<sub>2</sub></b>	53.28
<b>TiO<sub>2</sub></b>	1.07
<b>Al<sub>2</sub>O<sub>3</sub></b>	17.96
<b>Cr<sub>2</sub>O<sub>3</sub></b>	0.13
<b>FeO<sub>T</sub></b>	10.07
<b>MnO</b>	0.14
<b>MgO</b>	3.09
<b>CaO</b>	5.99
<b>Na<sub>2</sub>O</b>	3.97
<b>K<sub>2</sub>O</b>	0.85
<b>P<sub>2</sub>O<sub>5</sub></b>	1.80
<b>Cl</b>	1.20
<b>F</b>	0.33
<b>S</b>	0.12
<b>Total</b>	100
<b>H<sub>2</sub>O</b>	0.38

**Results from experimental degassing into a CO<sub>2</sub>-rich atmosphere:** The degassed samples consisted of glass and rare large vesicles. The quenched silica tube showed some extent of devitrification and rings of reaction precipitate some distance from the capsule.

After 6 hours of degassing into a CO<sub>2</sub>-rich atmosphere, the melt lost 100% water, 88% Cl, 83% F, and 100% S to the vapor phase. Importantly, this does not mean that the vapor phase is highly water-rich since the initial melt water content for the initial composition used is low. The bulk composition of the vapor given off, computed by difference between initial and degassed melt compositions, is 58 wt% Cl, 15 wt% F, 6.6 wt% S, and 21% water. Clearly, for this set of initial volatile contents, Cl is lost as not only HCl but also as volatile metal chlorides.

The change in melt volatile content and the bulk vapor composition inducing this change are shown in Figure 2a. The loss of all of the water and the greater loss of Cl than F induce major changes in the volatile load and relative abundances in the degassed magma.



**Figure 2.** a. Ternary diagram showing relative volatile abundances of H<sub>2</sub>O, Cl, and F in initial melt (M<sup>I</sup>), final degassed melt (M<sup>F</sup>), and vapor phase (v), b. Variation in melt Cl/F ratio with time, c. Percentage volatile loss during degassing.

These preliminary results suggest that shallow degassing could produce volcanic lithologies that were low in water content but still could contain significant amounts of halogens. Neither the volatile contents nor the ratios of volatile components of the initial melt are preserved during shallow degassing.

**Conclusions:** Shallow degassing of martian magmas can yield vapor compositions that deviate strongly from the volatile load of the magma. Understanding this is the first step in assessing the magmatic contribu-

tion to the martian atmosphere. Further experiments are being used to assess attainment of equilibrium, the effect of relative melt volatile abundance and melt composition on extent of degassing, and the effect of a CO<sub>2</sub>-rich atmosphere on magmatic degassing. This sets the stage for investigation of soil/magmatic vapor interactions.

**References:** [1] Mather, T.A. et al. (2003). [2] Michalski, J. R. and Niles, P. B. (2010) *Nature Geoscience* 3, 751-755. [3] Morris R.V. et al. (2010) *Science* 329, 421-424. [4] Nekvasil H. et al. (2009) *Meteoritics and Planetary Science* 44, 853-869.